Engagement in High Reliability Organizing (HRO): The Individual Matters

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Abstract

Understanding and engagement have a strange relationship with a situation. We fit the situation into our understanding, then use the situation to extend our understanding. We do this through engagement. Engagement is what bridges the gaps between objective knowledge and subjective experience. The situations we engage in are moving toward disorder. Engagement creates structure as it generates information. However, this is information in flux, meaning that engagement constantly updates our information as we continually revise our understanding—information changes in salience, meaning, and relevance. Effective engagement relies on attitudes, values, and reciprocal decision-making. Up close and engaged, the fog of war is the starting point for creating the structure.

"Effective engagement relies on attitudes, values, and reciprocal decision making. Up close, and engaged, the fog of war is the starting point for the creation of structure."

Introduction

There is a strange relation between how we understand and engage in a situation. Engagement can extend our understanding. Alternatively, our understanding can constrain engagement. In both relations, we use our understanding to engage. It would seem prudent to match the situation to a category, classification, standard, or plan – a concept to some. The person can then *objectively* know what to do and will gain a sense of security and confidence. The individual is developing *the confidence of belief* to encounter the unexpected. To others, confidence comes from the real-time ability to update information and revise beliefs for a changing situation. The person *subjectively* knows what to do, having *the confidence of action* when encountering the unexpected.

To be clear, the confidence of belief develops from knowledge by description. It is a measure of firmly held beliefs and/or thorough study of the process yet not tested in a dangerous context. The confidence of action more closely aligns with High-Reliability Organizing (HRO); it emerges from experience. Not the experience of repeated events but the experience of active sensemaking and action prevents negative consequences (1, 2). The experience is not only of continuous learning but of continuous *un*learning. Perhaps this latter trait prevents motivated reasoning and narcissism from developing in the HRO individual – we continuously unlearn as we learn. It is more than a deference to expertise. The leader develops in subordinates the expertise to which the leader will later defer (J. Douglas Orton, Center for Resilience Leadership, University of Michigan, personal communication, DvS).

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The difference in approaches is more than a division between objective and subjective knowledge, theory and practice (3), scientific rationality and practical experience (actual world) (4), discrete concepts and continuous perception (5), and the normative and pragmatic stances (6). The events that we engage in are made up of many small interactions (complexity science) and a few nonlinear rate-dependent interactions (deterministic chaos (7)). Novel properties then emerge from these interacting interactions. We have entered or have been put into place we do not seem to belong. However, we must respond to these emerging exigencies.

The last two sentences, our place and exigencies, describe how the emergence of novel properties makes an everyday space into one in which we do not belong. Our familiar everyday space has become a liminal space.

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Engagement bridges the gaps between objective knowledge and subjective experience, theory and practice, scientific rationality and the logic of practice, and the pragmatic and normative stance.

Complexity and deterministic chaos may seem to happen spontaneously or represent our loss of control over the system. They can

Table 1: Defined Terms

Term	Definition
Complexity	Many small linear interactions
Deterministic chaos	Rate-dependent nonlinear interactions between a few elements [7]
Self-organization	Structure from internal nonlinear processes [9]
Novel properties emerge	Dissipation of energy [10] and stochastic resonance [11]
Exigency	Urgent demand
Liminal space	Where we feel we don't belong
Red noise	Low frequency (*f*) events have greater power
Pink noise	1/*f* oscillations produce abrupt, rapid fluctuations and catastrophic failure

be described as contingent or stochastic, having apparent randomness, though with probabilistic functions. While unexpected events emerge from complexity and deterministic chaos, they are products of internal feedback from ordinary fluctuations in human behavior and the environment. This makes up everyday experience. They each develop from the red noise of human behavior and reddened noise from the environment. So, they are not new. They are the same thing but have a different order of magnitude and time course (8) (See Table 1).

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The introduction to this article describes two uses of our understanding for engagement of gaps. We can extend our knowledge or better understand the event (they are not mutually exclusive). When we allow gaps to interfere with our understanding, we gratuitously create stress responses that impair cognition or engender fear circuits that induce protective mechanisms (12, 13). Failure to understand the situation can be interpreted as a problem with knowledge and education, which leads to remedial education and training. Alternatively, we interpret failure to understand the situation as due to external circumstances, which we explain through complexity science, fractals, or deterministic chaos. Using this stance, the organization will develop objective education, training, preparation, and planning measures.

Another approach, one that draws on the use of understanding to extend knowledge, will prepare the organization for red or pink noise events. These organizations use engagement to bridge gaps. Because "organizations don't engage, people engage" (14), the focus moves away from the organization's structure and toward the individual's actions. It is the individual who identifies a discrepancy or disruption, and it is the individual who decides to engage. This is a subjective process, yet academic and organizational research focuses on measurable objective measures.

People act in a way that makes sense to them *at the moment*; no system or leader can prevent this. People have firmly held beliefs and operate in a stochastic environment. They must enter the liminal space where they do not belong, equipped only with observation and action (15)."I don't know what is happening, but I know what to do" – a Los Angeles Fire Department firefighter." HRO uniquely shapes the engagement that moves through and out of a liminal period" Karl Weick (personal communication).

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We reduce negative consequences and act to prevent an undesired outcome. This is the basis of pragmatism as philosophy (16), common sense decision-making (2), stress-induced symptoms, fear circuitry behaviors, amygdala-driven behaviors (12, 13), and current neuroscience research on how the brain works (17).

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When a person must act in a liminal space, they act to avoid consequences. In the HRO, they act to avoid *hidden* consequences for *immediate* results. Describing robots and artificial intelligence, John McCarthy (18) wrote, "We shall therefore say that a program has common sense if it automatically deduces for itself a sufficiently wide class of immediate consequences of anything it is told and what it already knows." The central reference for HRO activity is constantly referencing reality as it is experienced (1). HRO is"working in practice, not in theory" Todd R. LaPorte and Paula M. Consolini (19). *Reality drives action*.

Numerous disciplines discuss common sense as an entity: high-risk occupations (20), philosophy (21, 22), science (23), psychiatry (24), psychology (25, 26), anthropology (27), sociology (28,

29), social psychology (30), logic (18), reasoning (31), artificial intelligence (32), and robotics (33). We will use"practical common sense" to differentiate this academic entity from its colloquial use.

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Practical common sense is a form of practical intelligence for adaptation. In this usage, practical common sense better predicts success in everyday experiences, if not real-world survival. We can discuss practical common sense for high-risk situations with five components – motivation, intention, knowledge, heuristic processes, and action (2).

- *Motivation* – responsiveness to phenomena, specifically, pressure to correct disruptions and prevent failures
- *Intention* – to immediately act and adjust those actions, referencing an immediate, concrete goal
- *Knowledge* – tacit, concrete, background knowledge from experience that crosses domains
- *Heuristic processes* – intuition, insight, and learning from experience (34)
- *Action* – bridge gaps with engagement (6), think with motor cognition (1)

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In this article, we describe the subjective elements of engagement that individuals can readily learn at any level of knowledge and experience:

- Structure of the situation
  - Identification of structures
  - Generation of stable structures
- Information in flux
  - Use of imperfect information
  - Inference of new information
  - Generation of new information
- Attitudes and Values
  - HRO attitudes
  - HRO values
  - Value shift
- Decision-making
  - Feedback loops
  - Heuristics
  - Biases
- Stress responses
  - Demands versus expectations
  - Attributes and resources

We previously introduced Four Domains of Engagement (35) that we identified from our experience developing HROs (36). This article describes the practical *action* of engagement. The contents encompass the four domains, even if not specifically identified:

- categorization
- methods of decision making
- the significance of affective processes
- modulation of the stress and fear responses

The HRO considers potential outcomes and consequences, supporting engagement that reduces consequences. We then make a confident guess as to the *consequences* of our decisions, including the consequences of *not* acting. Not acting *is* an action, just as not deciding is a decision. Both are dangerous as those with less experience too quickly believe the situation has been resolved.

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The introduction of trauma centers in the late 1970s raised the question of resource utilization – does an overnight stay in the ICU indicate a patient who did not need admission? One of the authors (DvS) reviewed sequential admissions of trauma patients with a trauma surgeon. The question was not"Did the patient need operative management" but"Did *non-operative* management prevent an operation" admission to a trauma center with skilled nursing management allowed surgeons to avoid exploratory laparotomies. (This was before routine CT scans for internal injuries.) It has been the personal experience of the three authors that not acting while others urge active intervention is one of the more challenging aspects of managing a crisis.

This differs from failure to act in KarlWeick's model of *enactment*, which is more disregarding the consequences of not acting. Failure to act as enactment then becomes organizational knowledge that does not permit questioning (37).

Mastery in HRO comes not from a body of knowledge but from experienced sensemaking for consequences with the ability to solve problems never before encountered (38). Engagement puts that ability into action.

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People Make Sense through Engagement

Regardless of what people are taught or what the science of decision-making supports, *how people make sense of situations drives their decisions*. After the crisis has passed, however, they often describe their actions differently to help themselves understand or, in non-HRO organizations, to justify their decisions or actions (36).

> "During a crisis, there is not time to think about each specific bit of knowledge or experience that we depend on to make sense of imperfect information and ambiguity. But having those resources immediately accessible in our minds, we use them in a conceptual decision-making process to frame the decision. We essentially quickly come up with a paradigm of how to solve the problem. It is after the fact that we retrospectively begin to attribute specific reasons for the decisions that we made."
>
> - Capt. Chesley "Sully" Sullenberger (personal communication)

Perhaps the best identification of an HRO is engagement, and the hallmark of that engagement is the engagement of the outlier. While we more readily focus on the catastrophic "pink noise" event, the reddened noise-forcing function will more often damage the organization's operations. Forcing functions can self-resolve or respond to actions taken by actors on the line. This diminishes the importance of forcing functions as a threat – minor events are misinterpreted as non-consequential *probabilities* rather than displays of *possibilities*. In the HRO, any individual who encounters an outlier of any magnitude will engage because all outliers are indicators of destabilization. Engagement works to restore stability.

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While the brain engages to reduce the negative effect of consequences, the HRO directs engagement toward generating information and creating structure. We are not acting to reduce randomness or to select an action most likely to work. We act to identify what influences the system. That is why experienced operators focus less on"doing the right thing," that is, what will work, and focus instead on "doing it right," that is, moving the system toward resolution. Karlene Roberts used this idea to give the title for the first international HRO conference –"The Blue Collar Ivory Tower: Doing the Right Thing or Doing It Right" (DvS, personal communication).

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Probability measures have little contribution to accuracy. We can only combine probability distributions when the data comes from the same probability space. The High-Reliability Situation (HRS) becomes entangled with various probability spaces; we do not have joint probability distributions. In quantum theory and quantum cognition, this inability to combine probabilities is known as *contextuality* (39). Concepts change continuously under the influence of context, 'the change of state of the concept.' Concepts, then, can be modeled as a quantum entity influenced by the contexts of measurement (40).

Contextualization of concepts is not specific to quantum cognition:

- John Boyd, a US Air Force officer and strategist who created the OODA (Observe, Orient, Decide, and Act) Loop (41), described the contextualization of concepts as creation (synthesis of concepts by constructive induction) while separating the particulars from their previous domains (analysis of context through destructive deduction).
- Mike Zundel and Panagiotis Kokkalis (3) describe how we use concepts (theory) to work towards particular ends. Practical engagement comes from how we use an object (concepts), its function, and its purpose in context. We engage in "practical dealings with the world constitutive of our environment." Engagement does not come from the rational deliberation of concepts because concepts as "*scientific a priori understandings delimit the 'region' of what is there to be investigated*" (emphasis by the authors).
- Jörgen Sandberg and Haridimos Tsoukas (42) placed concepts as enactments determined through particular practices drawn from local contexts. Concepts are partly emergent properties, open-ended, that are created by our actions. This is similar to Boyd's creation of mental concepts during contextual synthesis.
- Karl Weick (5) warns against losing our perceptual contextual order by substituting an *a priori* conceptual order. The operator takes this warning as support for engagement: protect the perceptual contextual order we experience within the flow of events from the *a priori* conceptual order of the spectator, executive, administrator, or regulator (6). The continuous perceptual flow of context is knowledge by an acquaintance, while conceptualization in the interest of coordination and communication devolves into knowledge by

description.

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Operators have long resisted conceptualization. Conceptualization of contexts has consequences. Our brain engages to prevent the adverse effects of consequences. Vanessa Heggie captured this concern when she described the use of models to guide high-altitude mountain climbing: "Predicting what would happen to the first human beings to climb that high [27,000 feet] was therefore literally a matter of life or death – here inaccurate models could kill" (43). Operators hold tightly to engagement for safety reasons – engagement is the *contextualization* of concepts. Engagement makes models accurate.

Action as Information

A system is in an indefinite (dispersed) state *until a measurement or action is performed* on the system. All possible definite states have the potential for being actualized, but only one of them will become actual *upon measurement* when an action is taken. Such actions as a series of short action-response feedback loops create measurements. We can communicate these transient measurements as accurate "action responses," thereby converting our actions into information (44).

In a dynamic situation with an unstable structure, we cannot know the direction of our actions until we act. The sequence of those actions can affect the trajectory of events. Generated events from the sequence of our actions and responses have a transient existence. Because information plays a fundamental role in the unfolding of reality, the meaning of that information gives coherence to events. Thus, the reality emerges from the series of actual occasions (45).

"Because information plays a fundamental role in the unfolding of reality, it is the meaning of that information that gives coherence among events. Reality, thus, emerges out of the series of actual occasions."

In quantum cognition, the act of deciding *creates* the cognitive state. In other words, *engagement creates the cognitive state that supports engagement*.

Structure of the situation

We engage a system that is moving toward disorder – increasing entropy. Information becomes disordered as it is transmitted (46). This flux creates uncertainty. Our observations will shape the concepts we formulate, while our concepts shape our observations and inquiries (41). Accepting the uncertainty and incompleteness of our concepts reduces surprises (47).

Concepts, as described in the previous section, change continuously under the influence of context. John Boyd, a US Air Force officer and strategist who created the OODA (Observe, Orient, Decide, and Act) Loop, posited that "according to Gödel, we cannot—in general—determine the consistency, hence the character or nature, of an abstract system within itself." Analysis differentiates elements within the system, while synthesis with outside information integrates a solution from outside the system (41).

However, concepts are how we access the world. What Boyd describes is empiricism as engagement. He moves beyond the Kantian approach of *conceptual structuring* – facts must correspond to concepts allowing us to connect the world to those concepts (1, 48). While the Kantian approach gives us causality, we are concerned about consequences during the engagement.

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"How do we generate or create the mental concepts to support this decision-making activity?" John Boyd (41). Boyd's response to a disruption of observed reality parallels Karl Weick's sensemaking perspective that operators create what they focus on through repeated cycles. For Weick's sensemaking, the operator distinguishes cues within an ambiguous event to use for enactment toward a resolution that restores the disrupted activity (37, 49).

"Creativity is related to induction, synthesis, and integration since we proceed from unstructured bits and pieces to a new general pattern or concept. We call such action a creative or *constructive induction*…this creative induction is the separation of the particulars from their previous domains by the *destructive deduction*. Without this unstructuring, a new structure cannot be created—since the bits and pieces are still tied together as meaning within unchallenged domains or concepts, John Boyd (41).

"During an engagement, we follow many lines of simultaneous engagement as events unfold across a full spectrum of possible actions. Multiple challenges can best be solved in an integrated fashion to create synergy among disparate domains."

Boyd (41) considered these problems a dynamic *mystery* rather than a static puzzle. Adrian Wolfberg demonstrated this as "mys-

tery-solving," which relies on "full spectrum analysis." During an engagement, we follow many lines of simultaneous engagement as events unfold across a full spectrum of possible actions. Multiple challenges can best be solved in an integrated fashion to create synergy among disparate domains. "In full-spectrum analysis, the analyst examines not only multiple, possibly interrelated intelligence problems simultaneously but also considers contextual and influential factors that could affect the interim analysis of information and its interpretation" (50).

Practical Structuring

When coming on PICU service, one of the authors (DvS) observed that bedside staff had difficulty coherently presenting an unstable patient. The solution was quick and effective: create a list of *all* problems and measurements. Consistently, the first items most *salient* to bedside staff were "fluids, electrolytes, and nutrition," elements common to all hospitalized patients. This was due to the availability construct; the first things we think of are the most available to the brain, not the most important.

The team would then delete those elements that were measured with different methods. About one-quarter of the list was usually lined through. The team then grouped the remaining elements by the physiological system. One or two groupings could cause death, another two or three would keep the child in the PICU, and a few more would resolve with routine medical care.

After a few such cases, the residents learned to identify problems necessary for immediate engagement rapidly. Bedside staff no longer used conceptual ordering for their coordination and communication. Instead, they began to respond to relevant signals, whether the signal strength was strong or weak. That is, consequences contributed to the salience of a signal, relevance brought staff into engagement, and they gave meaning to information that supported engagement.

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In a resource-poor system, the individual who engages creates the structure…and makes the difference.

Information in flux

Reddened or pink-noise environments are information *insensitive*. More information (or data) makes the data messier or reveals covert, unexpected influences. With events in flux, current information quickly becomes antecedent information, entrained energy changes circumstances, and what was relevant becomes irrelevant.

We generate information through our actions. There is no wrong action, as every action creates a response, and every response changes an element from uncertain to certain. This uncovering of information and the generation of information is Shannon's Information (46). Claude Shannon laid the groundwork for the digital revolution by describing signals as having one of two values – certain OR uncertain. Information is the conversion of uncertainty to certainty. "Being certain" carries no information, but changing from uncertain to certain creates information.

"There is no wrong action as every action creates a response and every response changes an element from uncertain to certain."

In this sense, there is no error during an HRS (the High-Reliability Situation), as even what some would consider an error converts uncertainty to certainty. For the HRO, "error" has functions to identify boundaries of performance and operations, the "envelope" that HROs seek to expand. "Error" identifies a mismatch between what is known and uncertain or ambiguous. "Error" identifies an unexpected or unrecognized change in conditions or the environment.

"During an HRS, information is contextual, even ephemeral. What makes information different is how it is valued, not as weak signals but by its salience, relevance, and meaning."

Information during the HRS is imperfect but necessary. During an HRS, information is contextual, even ephemeral. What makes information different is its value, not as weak signals but by its *salience*, *relevance*, and *meaning*. The operator in the flux of a trajectory learns the salience of subtle and nuanced signals, identifies the relevance of information and gives meaning to changing information. Experience teaches us to change the level of salience, work with partial or contingent relevance, and shift the meaning of information as events evolve.

- The *salience* of signs and information prevents distraction when approaching an emergency.
- The *meaning* of information changes during events and also among participants. There is no useless information in an emergency.
- The *relevance* of information and how you use it is also situational.

"When you pay attention to the plan, you are ignoring information and become frustrated when the plan does not work," Chris Flowers, Training Officer, San Bernardino (California) Police Department, describing his experience responding to a terrorist incident and a school shooting (personal communication, DvS).

Salience, relevance, and meaning of information can be taught and learned. Salience, relevance, and meaning initiate engagement are produced by engagement and drive engagement.

Attitudes and Values

Attitudes represent predispositions in favor of or against an ele-

Table 2: The Attitudes of HRO

Characteristic [53]	Attitudes [36]
Preoccupation with failure	Attitude toward failure
Reluctance to simplify	Acceptance of the complexity of even simple events
Sensitivity to operations	Awareness of how one fits into the scheme of life Situation-centric versus person-centric
Commitment to resilience	Perseverance
Deference to expertise	Respect for the knowledge and experience of others

ment; attitudes *influence* behavior (51). While beliefs strongly influence behavior, their greater specificity limits their adaptability in uncertain and ambiguous situations. Attitudes have the notion of evaluation at their core (52) and are generalizable and less specific. Attitudes are adaptive to varying contexts. Conversely, values have a more substantial, more consistent effect on behaviors and are less context-dependence.

Attitudes

The generalizable character of attitudes gives the organization adaptability for varying contexts. The strength of values and their consistency makes organizational performance less context-dependent. The HRO uses this paradox to adapt to environmental change while maintaining organizational *stability* rapidly. The Five Characteristics of HRO (53) can be better understood as attitudes [Table 2] (36), but the values necessary for HRO (36) have not been discussed as well.

"The strength of values and their consistency makes organizational performance less context dependent. The HRO uses this paradox to rapidly adapt to environmental change while maintaining stability within the organization."

Values (36)

From their operational experience, two of the authors (DvS and TAM) identified five values that enable an HRO to perform and that are shared with its members through acculturation:

- *Dignity*. This means acknowledging the value of everybody's contribution.
- *Honesty*. What someone says represents the circumstances.
- *Humility*. The unexpected can happen to any of us; we can all fail. Humility can be learned, and it is the team's responsibility to discourage arrogance because no one is impervious to error actively. When an error or complication occurs, we immediately help: there is no reason to find someone to blame.
- *Empathy*. HROs work in challenging situations where people will fail, and it could be any of us doing the failing—there, but for the grace of God, go I. Empathy refers to our internal belief system toward the plight of others. People make the best decisions they can at the time; when things do not work out, we can support the person even if we disagree.
- *Duty*. We will not disappoint others; we have a duty to our larger community. Duty has a more significant, deeply held spiritual component that is internalized and comes from within. We engage to help others do their jobs; often, little things we can do will make someone else's work more challenging or straightforward.

Rapid Shifting of Values (36)

HROs work in two environments: the structured environments of routine operations, where preventing system failure is the priority, and the unstructured environments of a crisis, where an emergency response is a priority. Some values found in HROs seem to oppose each other, such as initiative and obedience. Others appear to be situational: what helps us one minute may have to be quickly discarded when circumstances change.

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Obedience and authority are part of preventing system failure, but creative problem-solving and the initiative to engage are necessary during an emergency. Having the ability to shift between values smoothly is one of the hallmarks of the HRO. This ability to rapidly develop initiative and creativity in an unstructured situation creates the "leader-leader" construct we desire for HROs. A "leader-follower" construct too quickly creates a docile member who awaits instructions.

Values are also situational. Our evaluation of what will help us and ensure safety will change as circumstances change. We must rely on people with a sense of duty toward the larger organization, a virtue, and their judgment during the event.

Decision-making

One of the authors (DvS), while creating a PICU residency program with ward and NICU nurses, noted that staff collected in-

formation and tended to make only minor decisions. To help in decision-making, the author offered several directives:

- *If it is reversible, then take action*. This required staff to know not only the desired effects but also the undesired effects.
- *Did the action make the situation better, worse, or no change?* This is a corollary from the above directive. Roughly, if better, then continue. If worse, stop – this gives new information about the situation. If there is no change, then evaluate whether it is the right dose, drug, or diagnosis.
- *Think from a decision box: What would happen if you acted too soon or too late?* What would happen if you give too much or too little? Acting within that box is relatively safe.

When considering intubating a child with severe status asthmaticus, Mark Rogers, RCP, RRT-NPS, suggested using a helium-oxygen mixture. Helium had not been used in the children's hospital, and the adult ICU had little, if any, experience using helium. One of the authors (DvS) asked Rogers how he would know it would work. He immediately described how he would know it worked or failed and gave a trial time that limited administration. This demonstrated to staff how to discuss introducing a new therapy and reassured the author that staff would neither stop the therapy before it could help nor push the therapy to where it could cause harm. Helium-oxygen therapy for status asthmaticus became standard in the PICU (54).

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Basic Problem Structure (36, 44)

Duncan Dieterly (55) described the three elements of a problem: the situation, intervention, and objective (Figure 1). Knowing all three makes the problem trivial; the situation defines the problem, which can be solved with rules and protocols. This is a matter of selecting the appropriate decision tree, algorithm, or clinical pathway.

In the HRO, we prepare for uncertain or unknown situations. Collecting data is unproductive because the problem changes. We approach these situations by developing a concrete objective. George Orr (56) expanded Dieterly's work by describing conditions with multiple situations, interventions, and objectives. At first, this may appear unclear, but by correlating these conditions with your experience, you readily expand decision-making for complex, chaos-driven situations.

Decomposing the Problem (36, 57)

If we cannot identify or reach an objective, we can decompose it into smaller, achievable objectives. For example, we can decompose the airway problem in resuscitation by manually acquiring the airway, identifying any obstruction in the mouth, identifying any obstruction in the upper or lower airway, and then protecting the airway.

It is common in an emergency to have two simultaneous objectives. We strive for the desired objective while striving for a less-desired, more readily achieved objective. In a sense, we hedge our bets. In high-risk situations, we work to achieve success while avoiding failure; this is a critical operational approach represented by the HRO principle of "preoccupation with failure." Avoiding failure is more than redundancy; it means being vigilant for things that can go wrong and responding to weak signals others miss or ignore. We work to increase our chances of success while decreasing our chances of failure. A French fighter pilot once described this to one of the authors (DvS): "If I can't accomplish my mission, I continue and support the other pilot; I work to increase the chance of success for his mission."

"Avoiding failure is more than redundancy; it means being vigilant for things that can go wrong and responding to weak signals others miss or ignore."

The OODA Loop

In 1968, John Boyd, a US Air Force officer and strategist who created the OODA (Observe, Orient, Decide, and Act) Loop, presented his concept of the OODA loop (Figure 2) (58).

We use the OODA loop in healthcare to outmaneuver a rapidly changing disease state (36, 57).

The OODA loop is a rapid, real-time interactive hypothesis development and testing cycle. To create the loop, the person **Observes, Orients, Decides, and Acts** then loops back to observe the effect of the action. The action creates the loop for a continuous cycle and gives the OODA loop its power and agility.

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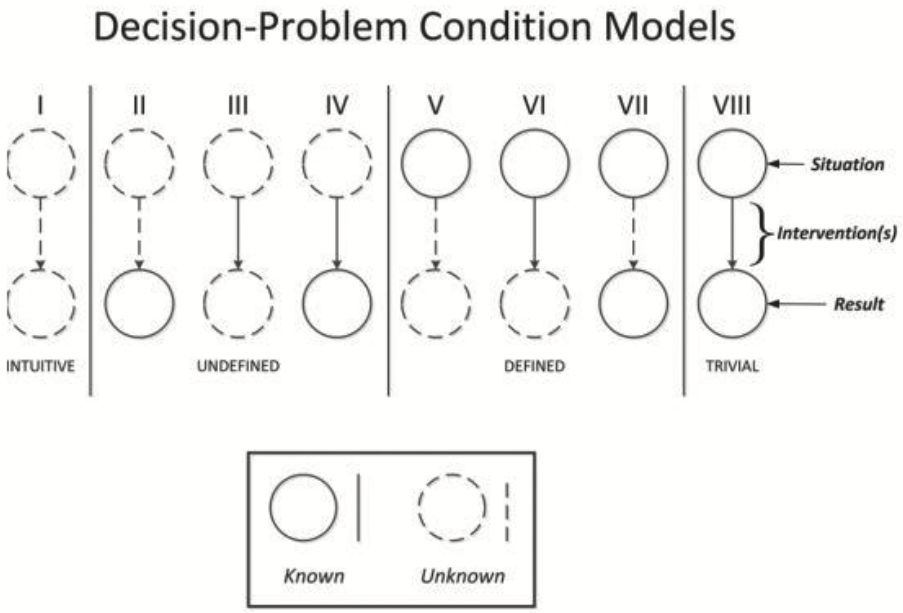
There need not be a consistent starting element. Weick observed that "one can start this sequence anywhere and move either in a clockwise or counterclockwise direction" (personal communication). Weick has described the utility of Boyd's OODA loop (in either sensemaking or enactment) by starting at A, the act phase (personal communication). Acting is the first step in engagement and is part of Weick's sensemaking.

Observe. An *attention* function for discrepancies, disruptions, and outliers does not require a complete analysis of the situation. The observe function also notices the responses to our just-completed action and whether we received the results we expected.

Orient. "Shapes the way we interact with the environment…The way we *observe*, the way we *decide*, the way we *act*." "*Seen as*



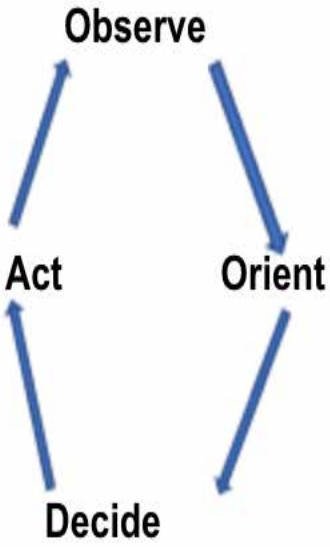


Figure 1 (left): Decision-problem condition models [55]
Figure 2 (right): Boyd's OODA Loop

a result, represents images, views, or impressions of the world shaped by *genetic heritage, cultural tradition, previous experiences*, and *unfolding circumstances*" John Boyd (58). In this function, we synthesize new information and build support for our decisions. (Some consider this an orientation to the circumstances, but the orientation function is much richer.) (59).

Decide. Rapidly generate a hypothesis. From the circumstances, it is operating in the affective domain of emotion, values, attitudes, and personal evaluation. Create new repertoires (59).

Act. Initiates the *loop action*, which acts like a control mechanism operating on the environment while changing people's perceptions of the environment. The loop action is a method to explore the situation while exploiting any path of least resistance. When we encounter friction as part of the feedback, we can observe whether we should pursue another path with less friction or identify the friction point as something significant that should remain in focus (56). The use of positive feedback through the loop action directs focus and actions toward paths of success, while negative feedback marks practical and safety boundaries that can act as a safety function.

"Boyd described the methods and benefits of a faster tempo: the ability to transition more rapidly than events change, develop more repertoires of action, free and open communication, interactive support, increased information sources to select from, and generation of new ideas that can be rapidly tested."

Loop. We calibrate our mental model with the actuality and responsiveness of the environment. Encountering resistance or friction, we rapidly resolve whether to change our approach or seek resources. This is not through speed or shortcuts but by increasing our tempo. Boyd described the methods and benefits of a faster tempo: the ability to transition more rapidly than events change, develop more repertoires of action, free and open communication, interactive support, increased information sources to select from, and generation of new ideas that can be rapidly tested (60).

Connecticut Paramedics (36)

Two paramedics arrived to find a woman in her late sixties lying face down in the street. They saw she was nonresponsive and pale. Her skin felt damp, and her oxygen saturation was in the low eighties, with a slow, weak heartbeat in the forties. On the EKG, they identified a regular electrical pattern except for premature ventricular contractions. The first thought was that she had had a cardiac event, so they began considering cardiac protocols. The two paramedics were unsure which protocol to use, but each paramedic had 15 years of experience and could see that she was dying. They began to feel helpless to stop her death.

While accomplishing this evaluation, they also made a rapid visual respiratory exam and observed very shallow breathing; they identified lower airway obstruction from the prolonged expiratory phase. This indicated treatment with a bronchodilator drug, something they would not have considered without the rapid five-point visual respiratory exam (61). They were not sure, however, if they should treat what could be a second disease, if the bronchodilator would work, or if the bronchodilator might stimulate the heart and cause the extra beats to fibrillate, creating cardiac arrest.

They decided to administer the drug and observe the response, which is something they would not have considered without the use of Boyd's OODA loop decision-making. After the bronchodilator treatment, the woman's chest expansion increased, the expiratory phase shortened, her oxygen saturation increased above 90 percent without supplemental oxygen, and she became alert. Most critically, her heart rate increased, and the premature ventricular contractions resolved. This woman's life was saved by treatment the paramedics had learned four months earlier.

Table 3. OODA Loop functions

Function	Description
Observe	Observe the situation Match prediction to response
Orient	Process and synthesis of observations Actual world function Culture, experience, physiology
Decide	Develop hypothesis; decide action
Act	Test hypothesis Interface between operator and environment
Loop	Effect of action

Reciprocal decision-making (44)

We have no time to vet information or evaluate events in a dynamic situation. We can rapidly observe feedback that is *directly associated with immediate action.* That is, we respond to the environment responding to us. Reciprocal decision-making describes how we act and observe the response to our action and how that response guides our following action. We learn what works through action. Decisions linked to action are probes to learn structure, redirect trajectory, create structure, and engage the threat. This is not simple feedback, a component of decision trees and algorithms.

"We have no time to vet information or evaluate events in a dynamic situation. We can rapidly observe feedback that is directly associated with immediate action. That is, we respond to the environment responding to us.

Feedback. This feedback is HRO trial-and-error learning. In this way, the environment acts upon the individual and organization, described by Bob Bea, Professor Emeritus, Civil Engineering, University of California, Berkeley (62), as *interactive, real-time risk assessment and management*.

Short feedback loops are more specific to our action and more readily accepted, rightly or wrongly, as causative. For example, instrumental anger or intimidation to gain staff control has a short feedback loop and is used for that effect in movies. The long and indirect feedback is disastrous and may be hidden, for example, with high staff attrition.

The time compression inherent to the flux of rapid, dynamic events confounds the real-time use of long or indirect feedback loops. To obtain short feedback loops, we must closely approach the environment, even entwining with the environment. Entering the situation shortens feedback loops, thus improving accuracy.

Negative and positive feedback. Feedback maintains homeostasis for stable operations within the environment, supports safety, and generates self-organization WHILE simultaneously bringing resolution to the event.

- Negative feedback corrects deviations from our desired state, ensuring safety; negative feedback marks our boundaries for safe operations.
- Positive feedback builds structure and supports our strength and resilience.

Heuristics and Biases

We have found four predominate heuristics that cause consequential bias and interfere with effective decision-making: availability, representativeness, confirmation bias, and over-conservative revision heuristics (Table 4). Motivated reasoning, a fifth bias but not from a heuristic, overly scrutinizes information that conflicts with closely held beliefs. This is not confirmation bias (36, 63).

Availability, called frequency bias, leads us to accept our first impression. Availability bias also occurs when redundant measurements of variables influence our perceptions. Availability also biases us toward precision and using numbers as quantitative information over qualitative values.

Acceptance of our first impression simplifies the situation. We too quickly stop developing more structure. Mentally listing 3-4 causes of the situation helps discipline the mind to continue thinking after the first acceptable answer.

Representativeness, closely tied in with complexity and "reluctance to simplify," leads us to regard partial information as complete information: what you see represents what is happening. This is difficult to break because practical common-sense problem-solving uses partial information (2), which is also all we have when we begin to engage. When we recognize the bias of representativeness, we can reevaluate the situation and update and revise our beliefs.

Confirmation bias derives from cognitive dissonance. To reduce dissonance, we search for confirming information. We look for evidence supporting our conclusions while ignoring disconfirming, discrepant data. Confirmation and availability biases are insidiously dangerous; an individual stops considering alternatives.

Overconservative revision biases us to require more information to stop an action than we initially required to start. We continue treatments long past when we would not have initiated the treatment. Once we start a treatment, we find it hard to stop, even when the reason for treating it is gone.

Error corrects heuristic bias. Though counterintuitive, the individual in these situations considers every action could be wrong. The author (DvS) served on a fire rescue ambulance in South Los Angeles ten years after the Watts Riots. The Crips and Pirus (later the Bloods) were expanding northward. Recognizing a gang member by clothing, behavior, stance, and countenance influenced our approach. The gang 'uniform' had yet to form. However, we had

Table 4: Heuristics and Biases

Heuristic	Bias
Availability	What you think of first is most important
Representativeness	What you see represents events
Confirmation bias	Seek supporting evidence
Overconservative revision	More information to stop than start
Motivated reasoning	Overly scrutinize evidence against strongly held beliefs

to discern the gang member from the 'wannabe' attempting to join or the youth adopting the gang appearance for their protection. Each needed to be treated differently. It was the feedback during our interactions that guided us. Sticking with the wrong approach could lead to injury or mistreatment of a youth trying to get by and stay in school. Every word and behavior could instantly be wrong.

"Error corrects heuristic bias. Though counterintuitive, the individual in these situations considers every action could be wrong."

Motivated reasoning is the automatic default mechanism for a person to defend their prior attitudes and actively challenge arguments incongruent with their firmly held beliefs. People are unaware of their use of motivated reasoning, which comes from motives to achieve an accurate conclusion or maintain a specific conclusion (64).

"Motivated reasoning is the automatic default mechanism for a person to defend their prior attitudes and actively challenge arguments incongruent with their strongly held beliefs."

Individuals protect cherished beliefs for several reasons (64, 65). Motivated reasoning enhances self-efficacy against a problem of self-control or gives utility for beliefs to counter a perceived weakness in a desired trait. Motivated reasoning also protects personal and social identity. Selective updating by information avoidance and asymmetric processing of good and bad information protects these beliefs (65).

Stress responses

Engagement is driven by the idea that "a failure *is* an option." The well-known stress and threat responses are commonly viewed as debilitating. This belief ignores their function during a crisis. Abstract thought distracts from focusing on new relevant information. Disregarding the proximity of a threat, whether temporally or spatially, reduces the time for effective action. This action is the inherent vice of stress (66).

"Engagement is driven by the idea that "failure is an option." The well-known stress and threat responses are commonly viewed as debilitating. This belief ignores their function during a crisis."

Threat identified through the sympathetic-adrenal-medullary axis (SAM) stimulates the paraventricular nucleus of the hypothalamus to release corticotropin-releasing factor (CRF) into the anterior pituitary *and* the locus coeruleus (LC). This release activates the hypothalamic-pituitary-adrenal (HPA) axis and the locus coeruleus-norepinephrine (LC-NE) system. The HPA axis suppresses the executive functions to support engagement, while the LC-NE system supports the cognition and behaviors necessary for engagement. CRF from the central nucleus of the amygdala may also activate the LC.

Do not get lost in the apparent complexity. Neuroscience has caught up to what veteran operators have long known. We engage in abrupt change, and engagement supports thinking during the crisis. Norepinephrine is rapidly released, supporting cognition. The slower release of cortisol will constrain abstract thinking to allow focus and rapid response. We see this is a crisis in the hospital – the individual who stands still for too long will unlikely participate in the emergency without some additional support.

We use stress-induced constraints on cognition and fear circuitry behaviors to overcome the inherent vice of stress and maladaptive fear-circuitry behaviors (12, 13). The vital HRO characteristic of modulating amygdala-driven behaviors is significant (12, 67-69).

Our neurological response to the threat from forcing functions or abrupt catastrophe creates a liminal space. We do not seem to belong in this space because our learned rules do not apply. It is intensely personal because we can never be sure others have the same experience. We must be acutely aware of our body's responses: "If your body is moving faster than your brain can think, then slow down. If you feel your eyes glaze over, slow down," William J. Corr, Captain of the Los Angeles Fire Department (personal communication). Corr was describing the shift from engagement to the disengaged thought that can occur in the liminal zone.

Engagement takes advantage of these neurological responses. Stress constrains the *executive functions:* the brain integrates, from opposite ends, perception, hastily created plans and motor activity. During a crisis, the hypothalamic-pituitary-adrenal (HPA) axis enables survival behaviors by releasing cortisol to "disarm" the executive functions. Novelty, uncertainty, and uncontrollability in executive functions cause stress responses. Fear circuitry behaviors at the subcortical level maintain a safe distance from the threat. Amygdala-driven behaviors as reflexes rapidly initiate protective behaviors.

"Our neurological response to threat from forcing functions or abrupt catastrophe creates a liminal space. This is the place we don't seem to belong because our learned rules don't apply. It is intensely personal because we can never be certain if others are having the same experience."

The human brain will release corticotropin-releasing factor (CRF), which goes to the hypothalamic-pituitary-adrenal axis (HPA), and the HPA terminate ongoing activity, suppresses executive functions, and impairs abstract cognition. Concurrently, CRF enters the locus coeruleus-norepinephrine system (LC-NE) to reorient cognition for attention and arousal – adaptive cognition is started, the individual focuses on behaviors, and engagement follows

Stress as a Problem

Viewing stress as an imbalance between demands and abilities is too simple for discussions of live-or-die situations or operating in dangerous contexts. We draw our model from Raymond Novaco's (70) work because of its fidelity to lived experience. (One of the authors, DvS, was a student of Novaco in 1978).

"Without differentiation of demands from expectations, stress debilitates staff, increases attrition, and impairs performance of individuals and the team. Expectations will drive out the more capable and empathic members."

Demands and expectations come from the environment. Demands are external to the individual and must be engaged. Expectations are social and subjective; they develop from our minds or those around us. Expectations are also how we judge success. Unfortunately, we too often find that the drive to meet expectations will occur at the expense of meeting demands. This apparent conflict became a central part of introducing new residents in the PICU and is vital for effective performance (DvS). Without differentiation of demands from expectations, stress debilitates staff, increases attrition, and impairs the performance of individuals and team performance. Expectations will drive out the more capable and empathic members.

Demands initiate engagement. We must keep the focus of engagement directed toward those demands.

We meet demands and expectations with our attributes and resources. Attributes refer to the individual's characteristics, knowledge, attitudes, decision-making abilities, and problem-solving capabilities. Resources are external to the person, which people can call upon while the event is ongoing. Because resources exist does not mean we can rely on them. "If you don't have it with you, then it doesn't exist," is a familiar fire department saying. This problem, how to operate in an austere situation, led one of the authors to develop a visual respiratory examination to replace blood gas analysis (71) and study retrograde intubation by paramedics (72) after the inability of paramedics to intubate an adolescent with pulmonary edema from commotio cordis.

Attributes and resources combine to give the individual the capabilities necessary for effective engagement. The HRO's goal is more than "life-long learning" the HRO continually increases the capabilities of the organization, teams, and individuals. The HRO views individuals as assets, the approach found in military services.

Family Presence during Resuscitation

Engagement creates the cognitive state necessary for engagement. This progression sounds tautological until you observe a novice move from observer to participant, then to engagement. Cognition differs in each of these three states. One of the authors (DvS) served on a fire rescue ambulance and engaged in thousands of resuscitations with family or friends present, if not actively helping. Rookies participated as valued members of the team. Therefore, it was surprising that beginners and families were routinely dismissed from healthcare. The author would then tell the parents that their child died, answer their questions about the resuscitation, and describe the life-saving efforts made by the team. When the family could later enter the room, they encountered a clean room.

Initially, the author would bring the family to the room while it had evidence of the effort made by the team. Because the custom was to present a clean room to the family, it took some time for staff to appreciate that when the family entered the room, they saw their child and evidence of the work involved in saving their child. Nurses thought a messy room reflected poorly on their efforts.

"Staff engaged with the family and could find they were able to comfort the family with small gestures or words, which had a greater effect than previous work to make the room clean and organized."

The final measure of bringing the family in *during* the resuscitation caused the greatest friction. The author would leave the room to bring the family to their child, as no staff member would do this. Written out like this, one can imagine the response from staff. The reality was different. Staff engaged with the family and could find they could comfort the family with small gestures or words, which had a more significant effect than previous work in making the room clean and organized. This program became internalized into the PICU and has since been published in the medical literature (73).

This change in resuscitation demonstrates engagement as a

quantum entity, described above in *Action as Information.* We cannot know the direction of our actions until we act. The sequence of those actions can affect the trajectory of events. Generated events from the sequence of our actions and responses have a transient existence. The meaning of that information gives coherence among events (45).

"We cannot know the direction of our actions until we act. The sequence of those actions can affect the trajectory of events. Generated events from the sequence of our actions and responses have a transient existence. It is the meaning of that information that gives coherence among events."

Responses are transient, allowing the staff member to rapidly intervene with the family or correct action if the family's response may be maladaptive, something we cannot do in a family meeting. Supportive interactions are significant; even a silent presence becomes support. Engagement dyads form and break, sometimes by voice, eyes, or a person's presence. Veterans and Neonatologists can give meaning to these interactions, which can reduce the stress experienced by staff.

Engaging the family in any form creates the cognitive state to continue engagement long after the emergency.

Situational Cognitive Distortions (13, 36, 74)

When not modulated, threats cause unrecognized situational cognitive distortions (13, 36), stress-induced disorders, fear circuitry disorders, and amygdala-driven behaviors (13, 36, 75, 76). Because we use our judgment to judge our judgment, these maladaptive threat effects only become visible in others or after failure. They can become normalized, making the ecology of fear inevitable and invisible (77).

Maladaptive stress and fear behaviors become normalized in high-risk environments when we do not recognize how the situation distorts our thinking. We call these *situational cognitive distortions* because, absent stress or fear, the individual operates at a high level of cognition (36, 57).

- The fight responses include anger and frustration
- The flight responses take the form of avoidance and distraction, often presenting as avoiding tasks, carrying out inconsequential tasks, responding to distractions, or addressing easily accomplished tasks to the detriment of essential efforts
- The fear-freeze response manifests as confusion or actual cognitive or physical freezing, the inability to recall knowledge, or impaired working memory
- Attentive freeze (threat-freeze) appears as an aroused pause immediately after an abrupt change that is misinterpreted as the fear-freeze response, but the attentive freeze is accompanied by focused attention to detail and mental preparation for action
- Tonic immobility appears as active refusal or avoidance to make a decision accompanied by intestinal discomfort (the latter is often not discussed)

Stress Capacity

It appears prudent to have stress management programs to reduce or help people respond to it. In dangerous contexts, the individual must be prepared to work in demanding situations; the focus becomes increasing stress capacity (78).

A US Army Green Beret working toward an MBA asked one of the authors (DvS) about risk management. The author pointed out that he does not *manage* risk. If he receives an assignment, he asks himself if he has the capabilities. If not, then what does he do to have the necessary capabilities? The same question is for his unit and onward through his command.

Engagement is about capabilities, not evaluating risk. The act of engagement capitalizes on stress-induced cognitive constraints to maintain focus. Fear-circuitry behaviors maintain a safe distance, which operates below the level of consciousness. In extreme situations, amygdala-driven behaviors are helpful to survive.

An HRO engages through individuals who detect discrepancies and disruptions by their salience. The individual interprets these outliers as early heralds of failure or as benign—events, and benign means they are noted and monitored, not ignored.

HRO can be described in terms of engagement, failure as information, and continuous adjustment of actions to accommodate the new information (observation by Errol van Stralen, Ancora Education). The HRO operates in a state of continuous or lifelong increase of capabilities. What this means for the individual is continuously increasing stress capacity.

"The HRO operates in a state of continuous or life-long increase of capabilities. What this means for the individual is continuously increasing stress capacity."

Conclusion

From our understanding, we identify what is salient, which is sufficiently important, and readily catches our attention. This object is the outlier as discrepancy or disruption. This perturbation is the early herald of failure caught during the covert, compensated state. At that moment, what was once irrelevant becomes relevant. Relevance is contextual and can also be role-specific, creating a requisite diversity of individual engagements. This relevance is how we fit the situation into our understanding.

As the environment responds to our actions, we respond to the environment responding to us. The cognitive state this creates influences the meaning we give to the information we generate and the structures we create. The act of engagement creates the cognitive state that supports engagement. The situation is now extending our understanding.

When we engage in the "fog of war," it is the act of engagement that gives meaning to our experience.

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Disclosures: No author has professional or financial relationships with any companies that are relevant to this study. There are no conflicts of interest or sources of funding to declare.

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Acknowledgments

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